IRRIGATION

IN

CALIFORNIA.

THE SAN JOAQUIN AND TULARE PLAINS.

NATURAL DRAINAGE SYSTEM—VOLUME OF DRAINAGE—METEOROLOGY—SOILS OF THE GREAT PLAINS AND THEIR SURFACES—A COMPREHENSIVE CANAL SYSTEM—PRACTICABLE FEATURES—FARMERS' CANAL OF MERCED—FRESNO CANAL—CHAPMAN'S CANAL—CENTERVILLE CANALS—PEOPLE'S CANAL—AND SAN JOAQUIN AND KING'S RIVER CANAL COMPANY'S CANAL—IRRIGATION IN PRACTICE.

A REVIEW OF THE WHOLE FIELD.

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IRRIGATION IN CALIFORNIA.

"My God! we're out of sight of land!" was the exclamation of the new comer, clutching his companion's arm as they drove together across the great plain that opens to the south beyond the San Joaquin river. The hills that bound the horizon as the traveler moves up the valley, had receded further and further on either hand, until he raised his eyes, the hills had sunk from sight, a boundless plain extended to meet the sky, and then broke from his lips the natural exclamation—"My God! we're out of sight of land!" No other language serves, to my mind, to express so vividly the vastness, the boundless extension of that empire which mocks the inadequacy of nomenclature in its designation as the San Joaquin Valley. Its extent is literally inconceivable. We may state the area in thousands of square miles or in millions of acres, but we have no conception of what is meant by those thousands of square miles or millions of acres. Even upon seeing this area, traveling through and across it, we fail to grasp the magnitude of the thing. It grows upon one as the Big Trees grow. You see them first and rather wonder that they do not look bigger; you see them again, and they do look bigger; again, and they swell and expand on your sight, and you grow to appreciate their immensity. At last they come to transcend all the preconceptions you had formed, and satiate the anticipation that had grown of those conceptions. Unlike the Trees, the San Joaquin and Tulare plains, which stretch for leagues upon leagues, drained into the San Joaquin river, at first view, not only equal but transcend the broadest expectation that can be entertained of their magnitude; but like the Trees they grow upon the imagination; they exalt and then fill it; they expand upon the mental vision, and in the end leave one with an idea of immensity, of an extension illimitable, exceeding even that that comes to one on the bosom of old Ocean. Then they grow in beauty as they grow in proportions. An infinite variety of contour and of color develops itself in what was at first monotony. The plains are fascinating with a fascination of their own, as luring as that of the ocean or the mountains; and the traveler who has first been wearied with a tiresome uniformity, and oppressed with the steady down-pour of summer heat, dazzled by the glare from the white skeletons of grasses or of more gleaming stubble, comes to find that an infinite variety and beauty lurk in the landscape; that to the hot noon, a cool eventide succeeds; that there are compensations even for the glare that tries and tires the unaccustomed eyes; and he ends by taking unto himself the soul and heart of the plain's life, and finding a very exultation in its largeness and freedom.

A recent American writer described his passage by rail across Bavaria. For more than two hundred miles of course, and on either hand, further than the eye could reach waved a sea of grain, unmarred by fence and almost unmarked by hedge, the sheet of green seemed to him not only a beautiful but a grand thing. He described it to his countrymen as something almost worth going to Europe to see. In a little while the traveler who shall visit California may write back to his friends of a grander sea of goodlier

growth, sweeping in one sheet across the vast bosom of California, until it waves against the foothills of the Sierra on the one hand, and runs its rippling line half way up the slopes of the Diablo range on the other—more than sixty miles away. How beautiful and grand soever this sight may be, a finer thing will be the lesson that it teaches—how all this goodliness and wealth have been wrought by man's intelligence, and energy and courage. It is he who will have made the waste into a garden and the desert to bloom. To landscapes as fair, Nature can point as the handiwork, but this one man shall claim for his own. The time will at last have come when he was to apply in California the art that had made of Babylon, China, India, Japan, Mexico and Peru, garden spots of earth. The nation youngest in birth had tardily learnt the earliest lesson that the oldest had to teach; but having learnt it, applies it with a decision and energy all her own. The era of irrigation becomes the third great epoch in the history of California, the point of her new departure upon a course that leads to a development of strength. Titanic measured by that of her compeers, and a wealth, imperial in its luxuriance.

SOILS AND SURFACES.

SOILS OF THE CALIFORNIA PLAINS.

Preliminary to any examination of the utility and detail of irrigation in California, the character of the soils and of their surfaces must be attentively considered. All our soils outside of the tule formation can be divided into two classes—adobes and loams. In general, these are clearly distinguished from each other, yet each passes by insensible degress into the other. The amount of area intermediate between adobe and loam is, however, so small as to be unimportant. The adobes, which are in general heavy and compact, are modified by the intermixture of gravels, of sand, and occasionally of alkalis, into lighter sorts. But the great bulk of adobe soil is compact, nearly free from grit of any kind, forming with water a highly tenacious mud, and contracting, as the water is expelled by heat, with the development of cracks on its surface and in its substance, while the bulk of the mass bakes into true brick—its degree of induration depending on the degree of heat applied. The effect of these peculiarities as a soil, is that the adobe, after absorbing water, forms, when exposed to the sun, a crust on top that, for a time, prevents loss of moisture by evaporation. Its compactness also prevents the escape of water by percolation, and equally resists its absorption of water by infiltration. Thus, after having become wet, it retains moisture for a season with singular tenacity. Later, when the formation of cracks has begun, it parts, through them, with the last particles of its moisture, and becomes indurated to a greater depth than any other quality of soil. In color, adobe may vary from black, through any shade of brown or red, to a gray—the tint depending on the presence of mineral or vegetable coloring matter. The loams, as distinguished from the adobes, are light and friable, and pass by insensible degrees from the more clayey heavier sorts by the infusion of increasing proportions of sand, through the lighter and sandy loams, to a pure sand. They are never free from grit; refuse to become fused by water into a smooth homogeneous mud; and, as the water is expelled by heat, are left with the particles imperfectly compacted, readily falling to pieces at a blow. The effect of these peculiarities as a soil, is that the loams, after absorbing water, part with it readily from the surface when exposed to the sun, but after the upper portion has become dried the moisture from deep portions is evaporated with slowness and difficulty. Their comparatively loose texture, however, permits the escape of water by percolation, and operates with equal favor to promote the absorption of water by infiltration. Thus a tract of loam adjacent to running water will absorb constantly from the stream and remain moist almost to the surface during the hottest season and without receiving any water from above. Adobe under like circumstances would bake to a brick, and in effect really repel infiltration from the running stream. Under the influence of rainfall loam will absorb the water until wetted through before it will shed it freely from its surface. Adobe absorbs with difficulty and will shed many cubic feet from its surface while slowly absorbing a few into its substance. And, supposing the two classes of soil to be irrigated, loam will absorb freely and allow the water to percolate as freely away; adobe will absorb slowly and retain what it gets, so long as cracks under the drying process do not penetrate its substance. After the surface is protected from the direct rays of the sun by vegetation these cracks are slow to form. The surface crust, which

sometimes bakes to a degree that checks the growth of vegetation, need not be allowed to do so under carefully applied irrigation. It will be readily seen from these hints that the detail of the application of irrigation will vary, according as the soils treated are adobe or loam; that in attaining the best results, the amount of water applied, the frequency of its application, and the copiousness of supply at different parts of the season and at different stages of crop-growth, will vary between considerable limits for adobe soils and for loams. Experience will in time develop these methods in their most favorable detail; it seems worth while here to point out to parties interested that this difference between adobe land and loam should never be lost sight of, nor the experience on soil of the one character be accepted as an infallible guide to attain the same results on soil of the other character.

THE ADOBE BELTS AND LOAM BOTTOMS.

Illustrations of these characteristics of the adobe soils and the loams are to be seen in the large way in the progress of settlement throughout the San Joaquin and Tulare plains. With the exception of two considerable belts that cross the plains on the east side, the loams are found adjacent to the river courses, usually constituting the "bottoms." These are the older settled lands of that section, occupied before irrigation or even railroads were in prospect. They are the Merced bottom, commencing at Snelling, the bottoms of King's river, the Four creeks, the Tule river, where the towns of Kingston, Visalia, Portersville, etc., have become established. Luxuriant crops of corn and vegetables have been grown on them, besides such wheat and barley as could find a local market. These are the lands upon which the culture of cotton has been successfully inaugurated. At the time they were settled up, occupation of the dry plains was not generally thought of. But some six years ago the planting of wheat began in a large way on the plains of Stanislaus county. With the construction of the railroad the farmers pushed into Merced, and later the "Alabama settlement" was formed in Fresno county. The rainfall throughout this region was but trifling, and yet in parts of it considerable crops were made. The towns of Modesto, in Stanislaus, and Merced, in Merced counties, grew up as the centers of extensive and growing farming communities. The efforts of the farmers at the Alabama settlement were a failure. Crops on the west side of the San Joaquin have in general been heavier under similar apparent conditions than those on the east side. Looking below the surface of this thing, what do we find? The soil of the west side is in general a compact adobe. A belt of the same soil sweeps across the east side at Modesto and another at Merced. The soil of the Alabama settlement is loam. The compact, tenacious adobe absorbed the trifling rainfall of that region, refused to give it up either by evaporation or percolation, retained sufficient moisture to bring forward and mature crops of wheat, barley and oats. Local exceptions to this result evince the operation of the same cause. At places the adobe is lighter than in others, owing to admixture of gravel and other elements. On such tracts the past season the crops were almost uniformly light. At the Alabama settlement we see the rich and deep but lighter loam yielding its moisture to the influence of evaporation, and failing to mature equal crops, while receiving an equal amount of rainfall with the heavy adobes further north. To land of this quality irrigation is essential. Without it the land is nearly valueless. With it there is scarcely an assignable limit to the variety and amount of crops which it will produce.

SURFACE OF THE PLAINS.

The San Joaquin and Tulare plains have an uniform slope from south to north at the rate of one foot to the mile, and from the mountains on either hand towards the line of greatest depression at the rate of eight feet to the mile. This uniformity of slope is to be understood in a general sense; when the engineer's level comes to be applied to it in detail important modifications are developed. On the east side of the river an important percentage of the entire surface, especially within twenty miles of the foothills of the Sierra, is "hog wallow." The surface thus designated may be represented on a small scale by covering the bottom of a milk pan with eggs distributed so that their longer axis shall lie at every irregularity of angle with one another, and then pour in water till it is more than half the depth of the layer of eggs. The surface of the water and the surfaces of those portions of the eggs which rise above it, together constitute a surface which is a fair representation of that of hog-wallow land. It is obvious that this is a sort of land that cannot be irrigated at all.

Besides the hog-wallow there is an impor-

tant area of land which may be designated as "billowy," the surface of which rises and falls in long undulations which, though slight, are sufficiently marked to manifest themselves to the unassisted eye. In irrigating a surface which departs from an absolute inclined plane, it is essential to carry the distributing ditches over lines which shall take in succession the most elevated points. On billowy lands such lines will be sinuous, increasing the length of ditch necessary to be constructed in order to serve a given area. Between said highest points the lines pass over depressions; the construction of each ditch will involve, therefore, an alternation of cuts and fills, increasing its cost per unit of length. Thus it is seen that these billowy lands require not only a greater length of ditch to irrigate a given area, but also that the ditch is more costly to construct. In the third place, it here becomes impossible to lay the water upon the land by a system of parallel furrows leading in a common direction away from a main farm ditch—it becomes necessary to lead the water from the summit of each "billow" by a system of furrows radiating from that point over its entire surface. Although it is practicable to do this, yet the detail of accomplishing it is so much more costly and troublesome than the same work would be on more level land, that it is evident the latter will command a steady preference and be first thus improved. The quantity of these more level lands is so enormous that years must elapse before they will be fully occupied or the occupation of the billowy lands be generally begun. These may therefore be added to the hog-wallow as being beyond the scope of any immediate scheme of irrigation. Besides which, it may be mentioned that most of the hog-wallow and much of the more level land is a shallow soil, underlaid by hard pan. Eliminating the hog-wallow and billowy land, which constitute perhaps nearly one-half of all the land on the east side of the San Joaquin, between the Tuolumne and King's rivers, we have left the vast area of the "west side"—the whole of which, north of Firebaugh's ferry, is nearly an absolute inclined plane, and also the larger part of the east side—a perfect plain to the eye, but upon which the instrument discloses an irregularity of surface to which the word "uneven" may be applied. "Uneven" though we call this, it is more even than any of the land north of Stockton, excepting some three or four isolated fields in the immediate vicinity of that city. It is so even that the eye cannot detect the direction of its inclination nor the slightest intimation of irregularity on the surface. But the engineer's level, determining the lines for distributing ditches by seeking the highest points, sends them sweeping around in great curves, tracing their course like the track of huge serpents over the plain. As the ditches follow the lines of elevation it follows that between them, and more or less nearly parallel to them, lie corresponding lines of greatest depression. The practical problem in the application of irrigation here will be to conduct the water from the high lines to the adjacent low ones on the shortest course—thus distributing it with equality to all parts of the intervening surface. To do this the irrigating furrows will maintain a direction generally perpendicular to the curve of the ditch, diverging from each other where the curve is convex, and converging where it is concave. The lines of checks from furrow to furrow will themselves be curved and substantially parallel with the curve of the ditch. Before, therefore, the farmer can proceed intelligently to make his irrigating furrows, the engineer must run him a set of contour lines sufficiently close to enable him to determine the direction of inclination in each field. These matters once ascertained and marked permanently upon the ground, the detail of irrigating these "uneven" lands will not differ in practice from that applicable to the true inclined plane surface of the "west side."

FORMATION OF THESE SOILS.

Without going profoundly into the geology of these regions, the method of the formation of soils differing thus widely in character having apparently only the one characteristic of unbounded fertility in common, can be explained. The hog-wallow, with its underlying hard-pan, shows the retreat of the broad foot of the glacier, leaving behind it the accumulated dust and debris of pulverized rock, arranged in its present form by the innumerable rills that issued from the retiring sheet of ice. The same rocks were ground up to produce the elements of the loam and of the adobe; we find only that these elements subsist in the two soils in different states of mechanical division. In the loams deposited by waters flowing in streams and rivers with a velocity sufficient to carry along much of the matter suspended in a state of extremely minute division, we find the constituent particles of coarser grain. It

would be difficult to believe that the vast areas of adobe constituting a large part of these plains, and often of great depth, were due to a surface wash of water like that of ordinary rainfall. But directly along the base of the foothills, overlying perhaps the hog-wallow or the loam of the original formation, we find a strip of true adobe, from a half mile to five or six miles wide, bearing the color of the hillside above it, which appears evidently to have been formed by rain-wash from the hill above. The effect might still appear too great to be attributable to this cause, till we learn that a considerable part of this strip of adobe—in some localities known as "dry bog"—has increased or been formed within a few years past; and a new conception of the energy of this cause comes with the knowledge that of one strip, five miles in width, more than half was formed, over what had been hog-wallow, during a single wet winter—that of 1864. Here we learn that the rain-wash does actually form adobe, that its energy is sufficient to form an extensive area of it in a single season; and accept without difficulty the conclusion that the same soil has been formed elsewhere by the same agency. This explanation at the same time accounts for the peculiarities of the adobe, the absence of grit in its composition, its difference from the loams, and the relative position of the two where they are found in juxtaposition.

Value of Drainage.

Knowing the area which drains into a water course and the amount of rainfall over that area, the volume of water that will be discharged can be calculated according to formulas that have been deduced from careful observations and measurements. The area drained is called the "cachment area" of the water course. Allowance is to be made for absorption of the rainfall into the soil, loss by evaporation, etc.; the remainder will be the theoretical discharge of the stream. These figures of cachment area and theoretical discharge for a number of the principal rivers of California are as follows. The areas are given in square miles, and the discharge in cubic feet per second:

Name of River.	*Cach. Area.*	*Discharge.*
Feather	3,939	444,666
Kern	2,382	340,882
American	1,889	285,532
King's	1,853	282,426
San Joaquin	1,630	256,649
Tuolumne	1,513	241,320
Yuba	1,329	220,111
Merced	1,072	187,077
Cache Creek	1,025	181,152

In order to get some idea of what these figures mean, suppose a river to have an average width of 500 feet between the banks, discharging a stream of water ten feet deep; the sectional area of the volume of water will be 5,000 square feet. A velocity of three miles per hour will be equal to about four and a half feet per second; and if the above volume be supposed to flow with this velocity, the amount discharged per second (disregarding friction) will be 22,500 cubic feet. A stream averaging 300 feet wide by three and a third feet deep will have a sectional area of 1,000 square feet; and, flowing with a velocity of two miles per hour (equal to say three feet per second), will discharge a volume of 3,000 cubic feet per second. With a sectional area of 2,000 square feet the discharge would be 6,000 cubic feet per second. These special cases will be recognized as approximating the actual discharge of several of the large streams above named, at their lower stages. We may pause to collate the relative discharge of canals of different sectional areas. The highest velocity safely allowable to the water within canal banks without endangering the stability of the banks is about two feet per second, or say one and a half miles per hour. A canal stream 120 feet wide on top, 84 feet on the bottom and 6 feet deep, will have a sectional area of 612 square feet. At a maximum velocity of one and a half miles per hour, the discharge per second would be 1,224 cubic feet. A width of stream 68 feet at top, 32 feet at bottom and 6 feet deep would have a sectional area of 300 square feet. At the above velocity the discharge would be 600 cubic feet per second. A width of 40 feet at top, 20 feet at bottom, 5 feet depth, would give sectional area 150 square feet, and a discharge of 300 cubic feet per second. It will be observed that in comparison with the rates of discharge above given for different rivers, the capacity of these canals is from one-tenth to one-twentieth of each stream. Thus, taking the sectional area of the San Joaquin river at its lowest stage at 3,000 square feet, and its rate of flow at two miles per hour, we remark that its discharge (9,000 cubic feet per second) is equal to the combined capacity of fifteen canals, each thirty-two feet on the bottom—the dimension of the San Joaquin and King's River Company's canal, which takes its water from that stream.

Recurring to the above table of the cachment areas and discharge of the rivers of

California, it is to be remarked that the actual discharge is far below the theoretical. For the purposes of irrigation the discrepancy is not important, for the actual discharge is seen to be ten times greater than can be applied to that purpose. But it is interesting to inquire what becomes of the water. We know the full amount that falls in each cachment basin; we know that it does not flow off through the visible drainage channel; the inference is inevitable that a great part of it passes away through underground strata of gravel and other permeable composition. If this be true, we shall expect two things: First, that the existence of such underground water-flow would be disclosed by borings; and second, that some of these strata would be intersected from time to time by the water courses, which would then receive the flow of each stratum, resulting probably in an appreciable increase in the volume of water flowing in such channel. Both of these conditions are found to exist in fact. In connection with the surveys for the canals now under construction, extensive borings were made at the San Joaquin river, its tributaries and in the vicinity of Tulare lake. In each instance the existence of an extensive underground drainage was disclosed. The fact that the main river courses receive accessions to their volume of flow from these sources is familiarly illustrated throughout their length. The San Joaquin at Firebaugh's runs one-half more water than it does at the railroad crossing, though in the interval it does not receive a single tributary. King's river at Kingston flows double the volume that it does at the upper ferry, and at the upper ferry it flows one-half more water than at Centerville, yet it receives no tributary. Other streams that flow a large volume of water at one point, a few miles lower are dry beds. In fact, there is scarcely a California stream that does not illustrate the fact of underground drainage by one or both of these classes of phenomena.

Tulare lake, and the drainage system in which it plays the part of reservoir, illustrates underground drainage upon a great scale. During a portion of the year the surface of this lake is raised sufficiently to discharge by overflow the surplus of waters poured into it by Kern, Tule and King's rivers and Kaweah creek. But after the waters have subsided so that overflow ceases, those large rivers continue to discharge into the lake an amount of water equal to the discharge of the American and Yuba rivers and Cache creek combined--exceeding many fold the greatest possible amount of depletion by evaporation. Yet the lake contrives to get rid of a greater amount of water than it receives; the level of the surface is slowly lowered throughout the season; underground drainage here becomes the only possible means of efflux; and in fact the borings made adjacent to the lake disclose the existence of a copious underground flow—the measure of which is indicated by the combined influx from Kern and King's rivers. When the levees shall be constructed which have been proposed in connection with a general irrigation system, converting the lake into a reservoir and raising its surface so that its waters can be conducted out over the surface of the soil, the entire volume of water then conducted by the canals will be an addition to the supply available for irrigation and transportation without abstracting any part of that which now flows through the natural drainage courses. The same thing may be true of other irrigation works depending on this matter of underground drainage, as it operates upon the streams and at the point whence their supply is obtained. Thus the effect of the San Joaquin and King's River Canal upon the volume of water flowing in the San Joaquin has been tested by the experiment of closing the head-gates so as to exclude all water from the canal. The effect was to raise the water in the river below the head works exactly one inch! The explanation of this apparent anomaly is, that about this portion of its course the San Joaquin receives an important accession of volume from underground drainage—probably from the Tulare lake drainage; thus its waters are maintained at a given level, whether one canal full be abstracted or not. It is possible that an amount of water might be taken from the San Joaquin at this point equal to the volume discharged into the lake by King's river without materially decreasing its volume. Such an amount would require three or four canals of the size of the present one. The fact that one-tenth of the visible volume of the river at its lowest stage can be taken from it with a decrease of volume which is barely appreciable (lowering the surface one inch) is very remarkable and of a high degree of scientific interest.

METEOROLOGY.

Besides the absence of rainfall, explained above, other important features of the mete-

orology of this region are the winds and dews. Throughout the summer a fierce wind from the northward, parallel with the main axis of the plains, draws over them from one end to the other. With some local exceptions it appears to increase in intensity proceeding southward. It is due to the heating of the table lands and deserts lying beyond the Tejon, rarifying the atmosphere over their surface, which rises, while a portion of that from the California plains rushes in to fill its place. These gales rise daily soon after sunrise, and continue to blow till towards midnight. It follows that large areas of the plains, fitted by soil, irrigation and other circumstances for the cultivation of cotton, hops and such crops of the more valuable sorts, will be unavailable therefor at present, and until trees—all kinds of which appear to flourish luxuriantly under the stimulus of irrigation—shall have been planted and attained sufficient size to afford protection from this zephyr of truly California type. Where the native trees now grow, the protection is often sufficient, and amid the stately groves of Tulare county every crop can be raised with profusion. The absence of dews throughout all the region north of Tulare lake must also be noticed. To the east of that lake the dews appear again and are often heavy. What differences, if any, in the character and growth of some of the more valuable crops in these several localities may become attributable to this circumstance, experience must be left to determine.

IRRIGATION.

NATURAL DRAINAGE SYSTEM—THE KERN COUNTRY.

The natural drainage system of the country, embraced in what are called the San Joaquin and Tulare "valleys" (a misleading word to designate those vast, and, to the eye, boundless plains), is as follows:

At the extreme south the Kern country is a grand circular plain around which sweep, for three-fourths of its circumference, the Sierra and coast mountain systems. These limit it on the east and west respectively, joining their areas of upheaval to form its southern boundary. This country is open to the north (the direction of the flow of its drainage), where it is bounded by Tulare lake. At its upper or southern end, are two small lakes—Buena Vista and Kern. All these southern lakes, it must be understood, are not basins of water surrounded by hills—they are merely areas of the general plain which shelve downward at a slope so slight as to be imperceptible to the eye. A rise of a few feet in their water, extends their surface for several miles over the surrounding plains. In fact a rise of only three or four feet above ordinary high level in Tulare lake, serves to place the entire country for an area, embracing hundreds of square miles, under water. At the ordinary summer stage of water cattle are seen feeding out in the lake on the long tule grasses, a distance of a half mile to a mile from its margin, standing knee-deep to belly-deep in the water. We see, then, that the drainage system of the Kern plains and their bounding mountains is, that the rain-fall is first poured into Buena Vista and Kern lakes at the upper or southern boundary of the plain, whence it flows down into Tulare lake at the northern boundary. On the eastern side, Kern river and other considerable channels pour the waters from the adjacent portion of the Sierras directly into Tulare lake. On the western side, the mountains approach the lake, and at a single point send down a spur to its shore.

Natural Drainage—Tulare.

A second great natural division of the country, and lying next north of Kern, is that which drains directly into Tulare lake, embracing the whole of Tulare county and so much of Fresno county as is drained by King's river, which empties into the lake near its northern extremity. The civil and natural division between Kern and Tulare counties, is the line of Tule river, which empties into the eastern side of Tulare lake, near its center. Going north from the Tule we come next to the considerable river known as Kaweah creek, which, dividing east of Visalia into four principal channels, gives name to the "Four-creek Country" or Visalia Delta; these creeks also flow into the lake. Next north comes the great King's river, discharging the rainfall of the stupendous King's canyon and its tributary mountain chasms, the grandeur and sublimity of whose scenery have been the inspiration of some of the most glowing descriptions given by Clarence King and other explorers of the High Sierra. In these descriptions it will be remembered that the High Sierra, as seen from Mounts Tyndall, Whitney or other of its loftier summits, presents itself as a wild sea of stupendous peaks, tossed into the sky in titanic confusion, and deeply cleft by two principal

chasms, which start from a common point and sweep away—the one northwardly and the other southerly—receiving the waters which are precipitated in the form of rain and snow upon that entire mountain system, and carrying it down toward the plain. The northerly cleft is the canyon of King's river; that to the southward is the channel of the Kern. Soon after the early rainfalls, and during the melting of the snows, these canyons are the channels of deep, broad, boiling torrents, pouring down at a high velocity, streams of water which have a cross-section of thousands of square feet, into the great natural reservoir of Tulare lake. This is soon raised above the level of its natural barriers, and sends down the surplus waters through Fresno slough into the San Joaquin river.

Natural Drainage—The San Joaquin.

North from King's river lies the third and last natural drainage division of this country, embracing the area drained directly by the San Joaquin river, with its tributaries, the Fresno, the Merced, the Tuolumne, the Stanislaus and a number of lesser but not unimportant streams, as the Cottonwood, the Chowchilla, etc. Observe that all these streams flow eastward from the Sierra. On the west of the river the comparatively low mountain system causes little condensation and rainfall, and that which it does cause takes place principally on the western slopes of the hills toward the coast, and forms the various small streams that run into the ocean at Monterey bay, and thence southwardly. The moisture contained in the lower strata of atmosphere coming inland from the ocean, is thus principally condensed and precipitated by the hills before it reaches the San Joaquin country. The moisture contained in the higher strata continues on its eastward course uncondensed, until precipitated by the High Sierra. From the rugged sides of these mountains it is sent down in torrential flow through its natural channels to the bay. Thus it comes that the thirsting plains of the San Joaquin are first cheated of the rainfall that might make them the garden of California, and are next mocked by the rush of the same waters flowing between parched river banks, idly to the sea. And thus it comes that there are no important tributaries flowing from its west side into the San Joaquin. At the lowest stage of these streams the past summer, the San Joaquin at Firebaugh's ferry, above the points of junction of its important tributaries, flowed a body of water with a cross-section exceeding 3,000 square feet, to which the Tuolumne afterwards added its stream, then running with a section of 600 square feet. The stream of King's river at the same date, after the upper ferries had stopped on account of the low stage of water, was running with a cross-section of about 1,000 square feet.

CANALS FOR IRRIGATION AND TRANSPORTATION.

A COMPREHENSIVE CANAL SYSTEM.

"A comprehensive Canal and Irrigation system" may be illustrated by the more familiar idea of a comprehensive railway system. It is easily understood that the latter ought to consist of two trunks running, one on the east side of the San Joaquin river and one on the west side, combining to form a main stem from a point—say at Bantas, and thence along a natural grade by the straits of Carquinez to deep water. Branches at proper points, running up to the foothills, would complete the system. A comprehensive canal system (such, for example, as might be wisely undertaken under a more efficient political system than ours, as a Government work), would consist of two main canals, one starting from Kern lake and the other from Buena Vista, running northwardly on either side of the great plains. These canals should be laid out on the least practicable grade, so as to hug the foot line of the hills, and thus embrace, sloping away from them to the central line of depression, the entire area upon which irrigating water could be brought. As the great natural streams were successively encountered, the necessary portion of their waters could be utilized to maintain the canals at full flow. Such a foothill canal could extend continuously from the south, along the Sierra, until it made a junction with another like work coming down the edge of the Sacramento plains from the north. This northern canal would take its rise in the streams draining that area of upheaval of which Mount Shasta is the dominating peak. From the same system of streams, a like canal would come down on the west side of the Sacramento plains, and terminate at the straits of Carquinez. On the west side of the San Joaquin plains a corresponding canal, starting from the Kern lakes, would hug the western foothills till it reached the bay at or below Antioch in Contra Costa county. By such a system of main exterior canals, the entire interior plains of the State would be

embraced, their area lying below the level of the canals and sloping away from them at a generally uniform descent of eight feet to the mile.

To apply the system, branch canals should be run from the mains at proper points across the plains eastwardly, and westerly towards their central lines of drainage—the Sacramento and San Joaquin rivers. These branches would be the service canals for the distribution of water for irrigation. The main outside canals would have a width of probably 120 feet. The branch or service canals would have a width of say 70 feet. Thus, these two parts of the system would be canals for navigation and transportation, as well as for irrigation. From the branch or service canals the water would be taken by distributing ditches (say 10 feet wide), and delivered from these directly into the farm ditch. The main, the branch and the distributing works would be constructed as parts of the irrigation system; the farm ditch would be constructed by the land owner and would be private poverty, to be maintained and operated at private expense, and as a permanent improvement upon the land.

But a system as thus constructed would, in the San Joaquin country, be incomplete for the reasons: First, that the main river of that section is not navigable the year round; and second, that the periodical overflow of Tulare lake, King's river, etc., has not been provided for. A levee thrown around the lake converts it into a vast reservoir of nearly 800 square miles area, storing up the waters that now run to waste at a time when, the lower streams being full, they are not even needed in aid of navigation. But the rivers emptying into the lake, for miles before they reach it, flow through a country so nearly level, that if the lake alone were leveed, its waters would tend to rise higher than the banks of the tributary rivers, and so would flow over these into the plains. It would be necessary, therefore, at the same time to construct levees along the banks of the lower portions of these rivers to a hight equal to that constructed around the lake. A main canal extending from the great natural reservoir thus improved, down the valley to the head of permanent navigation, would then complete "a comprehensive canal system" for transportation and irrigation in the San Joaquin country. With the entire system as thus sketched, constructed, it would be complete as well as comprehensive for the whole interior of California.

A PRACTICABLE SYSTEM.

Works of the magnitude indicated could be constructed only by a government. Public opinion would widely refuse to allow any branch of our existing government system to undertake the work. Those portions of the works which are subsidiary to the great exterior works may be constructed independently of these and independently of each other. Taken singly, they are not beyond the ability of private enterprise to manage. In time the several parts may grow into a comprehensive whole. Meanwhile, each part may be as efficient to perform its individual function as it could be in the completed system. Take first the case of what we have called the branch canals. These would start from the main canal—some of them, perhaps, at the point of crossing a river. Such an one can be constructed at present. Instead of taking its water from the main canal, let it take water directly from the river. This need not interfere with the ultimate construction of the main canal. Having taken the water, let the canal be constructed on the proper line; that is to say, the most elevated level practicable course, so as to serve the largest practicable area of ground. When completed, this will be a canal for navigation and transportation. On the east side of the San Joaquin it will intersect the railroad as a branch road would do, bringing produce to it. This is the class of works which are under actual construction at present. Prominent among them are the Farmers' Canal, of Merced; the Fresno Canal (Friedlander's), at Borden Station in the Alabama settlement; Chapman's Canal, east of Firebaugh's; the People's Canal, above Kingston, on lower King's river; the Centerville and Fresno City canals (San Joaquin Land Association's), on upper King's river. The San Joaquin and King's river company's canal, the most extensive work of all, is a part of the main central canal to run from Tulare Lake to tide water at Antioch. These works, all of which are important, not only locally, but as possible parts of the grand comprehensive system of the future, merit particular description. The general public, outside of the parties directly interested and residents of the localities affected, has not yet begun to realize what is doing in these directions, both by self-helpful local associations and by the capitalists, who, as

land holders, have undertaken these works as a means of bringing their vast possessions into market.

CANALS UNDER CONSTRUCTION.

THE FRESNO CANAL.

A very good idea of the general plan and method of irrigation works can be obtained from the Fresno river canal now being constructed by Mr. Isaac Friedlander, near Borden station, on the railroad, in Fresno county, to irrigate the lands of the "Alabama settlement," together with other extensive tracts owned by that gentleman and others. In this case the main canal commences at the Fresno river at a point about two miles east of the railroad, and is constructed thence southwardly to Cottonwood creek, a distance of four miles. It is proposed to proceed with the canal south from the Cottonwood, crossing that stream, continuing its course to an intersection with the San Joaquin, a distance of about nine miles. For the purpose of constructing the canal a careful exploration was made by Mr. Alfred Poett, civil engineer, in 1871, of the Fresno river, following its course to the headwaters; also of Snow creek and other streams, with a view of adding to the present supply given by the Fresno, The examination of the Fresno, about three miles above the present railroad crossing, showed by borings taken that a large stream of water filtered through its bed even during the driest season. In view of this fact it was thought worth while to construct a tight dam, made solid and well, down into the hard pan strata under the sand, thereby holding the water, in the hope thus to secure water enough for irrigation, not only during the spring but also enough during the summer, for a second crop. The latter part of the object aimed at has not been secured. Although the tight dam has been built deep below the sands of the river bed, the water continues to flow through these stratas, showing that it makes its way around the ends of the dam.

In November, 1872, the present works were commenced, too late in the season for favorable work. The winter rains not only interfered with the progress of the dam, but tested its stability by a very trying test. The dam and headgates are now completed, also the canal from the Fresno to the Cottonwood, the final finishing touches having been given in the latter part of July, when the three distributing ditches were also completed to the railroad—a distance of two miles for each, or ten miles of main and distributing canal in all.

The dam is a timber structure, 311 feet long and raising the water six feet above original level, constructed of two rows of main piles from 20 to 35 feet long, planted 10 feet apart, the points firmly imbedded in a stratum of clay. Between the main piles is a double row of 4-inch sheet piles. The space between the two rows of piling is filled in solid and planked on top. The action of the water during freshets on the river bed below the dam is guarded against by a timber "apron" of 4-inch planking—an incline set to receive the water as it tumbles over the dam and shed it off on its course down stream, upon a thick layer of loose rock work. When the water reaches the top of the dam it is backed up, forming a lake one mile long by 500 feet wide, with an average depth of 5 to 6 feet. The water is turned into the canal by the opening of six gates into a flume or timber box 30 feet wide. Through this fluming it is turned into the canal.

This work is constructed with an uniform width at the bottom of 20 feet. The sides rise on a slope of 1 foot vertical to 2 feet horizontal, to a hight of 8 feet, carrying 6 feet of water. This is the water way or channel which is expected to flow full of water. The water at the surface is therefore 44 feet wide. The banks are carried up higher on a steeper slope, and on the top are 4½ feet wide. The canal is taken from the river at the highest point necessary to convey water to the irrigable ground. This point is in a ridge of "hog wallow." The cutting through this ground is quite deep, and at the river the canal work has the imposing appearance of a railway cutting. It is run on a grade of six inches to the mile, which will give a flow of the water at a rate of 1¼ miles per hour, and will discharge, when running full, 360 cubic feet of water per second. This nearly horizontal grade soon brings the canal through the "hog wallow" ridge and out upon the upper edge of the general plain. It follows the main course of this edge, cutting through two other ridges of hog wallow, which make down upon the plains in its course to the Cottonwood. Where cutting for the canal has to be done, the method of doing the work is the same as that pursued for railway cutting. The bottom is plowed up and the loose earth scooped up the

shelving sides with horse-scrapers. In the "hogwallow" a hard pan is encountered which is blasted, and adds materially to the cost of the work. When the bottom of the canal comes out upon the surface of the general plain, the banks are formed by scraping up the earth material from the outside. Plow-furrows are run along outside the base of the proposed bank, and the loosened earth scooped up into long ridges by scrapers. These ridges are afterward carefully trimmed and dressed smoothly and constitute the banks of the canal. They are made as smooth and even as the flower-beds of a city garden, or the terraces of the Capitol grounds. Their outside slope is one foot vertical to one and one-half foot horizontal. From the other dimensions already given, it will be seen that a cross section of these banks is as follows: Top, 4½ feet; bottom, 32½ feet; hight, 8 feet; cross section, 148 square feet; cubic yards of earth to be moved for each 100 feet of canal (two banks), 1,096. Contract price for this kind of work in ordinary ground, say 15 cents per yard; cost of canal in this good sort of ground, $164 40 per 100 feet, or say $8,680 32 per mile. When the canal is cut to a depth of four feet, instead of being built wholly above ground, the amount of earth to be moved for each 100 feet of length, is 414 yards—costing, at the above price, say $3,-420 per mile. The length of canal constructed to Cottonwood creek is four miles; projected extension to the San Joaquin, nine miles more, or say thirteen miles.

Water is delivered from the canal into the Main Distributing Ditches by an arrangement of gates and fluming or boxing. The bank of the canal is rounded or curved to approach the gates. The main distributing ditches are 10 feet wide at the bottom; slope of bank inside, 1 foot vertical to 2 feet horizontal; width on top, 2 feet; hight, 2 feet; number of cubic yards of earth to each 100 feet of bank, 20; cost to construct at 15 cents per yard for each 100 feet of ditch (two banks) $6; cost per mile, say $316 80. The work upon these main distributing ditches is done in the same way as upon the canal; lying almost wholly on the surface of the ground, there is little or no cutting and the banks are constructed by plowing outside their line, scraping up the plowed soil to form the bank, and then dressing and trimming. These main distributing ditches have a grade which depends on the ground, the maximum rate being 33 inches to the mile; this should give a rate of flow of nearly 1½ miles per hour, and discharge for each ditch 45 cubic feet of water per second.

The amount of discharge above noted for the canal (360 cubic feet per second) will be adequate to give from three to four inches in depth every 40 days during the season to an area of 72,000 acres. When running only four feet full the discharge would irrigate in the same way 35,000 acres.

I have described these works at some length, because they constitute in some sort model works, and because they make by no means the most favorable showing for irrigation enterprise. They have been costly for their extent, owing largely to the fact that the head works (dam, etc.) were constructed during the winter with the river running full; and second, because the greater part of the canal from the beginning to Cottonwood creek passes through a hard pan cement rock. The total cost of the works approximates $60,000; while for the same character of works, constructing the head works during the dry season and with ordinary earthwork in place of hard-pan, $40,000 would suffice. The work on the extension of this canal beyond the Cottonwood will be of this lighter character.

Some idea of the part to be played by irrigation in the internal economy of the State may be formed by observing some of the results rendered possible by this comparatively small work. Suppose the 72,000 acres which it irrigates to be cultivated to wheat. The result is a crop of 1,800,000 centals, or say, 90,000 tons; value at the railroad, which passes through the land, $2 500,000. It is not likely that any crop less valuable than wheat will be raised. Five thousand acres planted to alfalfa would more than maintain all the dairies in Marin county. If it shall prove that the land is suited for cotton, a crop to the value of $5,760,000 should be annually taken from this area. And yet the dimensions of this irrigation system, in comparison with the works in progress elsewhere, and these in comparison with the comprehensive works projected, are very small. The imagination refuses to follow the effects of general irrigation as displayed by the experience already had, to their legitimate consequences.

The dimensions that ought to be given to a canal in order that it may irrigate a particular area, or the area that may be irrigated from a canal of particular dimensions, may

be deduced from the following data: The "duty" of one cubic foot of water per second flowing through a canal is to irrigate 200 acres of land, giving to the same during the season a depth of eleven and a half inches or 1,500 cubic yards of water per acre. In many places, if not usually, one half this amount is expected to suffice; and in that case the "duty" of one cubic foot per second would be 400 acres.

The highest velocity permissible where the canal banks are of loose earth, as in the California canals, is two feet per second (say one and a third miles per hour). In a canal of favorable section—flowing say five feet of water on a twenty foot base, and with side slopes of two to one—the rates of flow would be approximately as follows: On a fall of nine inches to the mile, two feet per second; on a fall of six inches to the mile, one and three-quarters feet per second; on a fall of three inches to the mile, one and a quarter feet per second.

If the water be shallower, the width less, or the slope of the banks flatter, the rate of flow, at the above rates of fall, would be somewhat less; but the above figures may be taken in order to get at approximations to the practical work that may be expected of a canal of given dimensions.

FARMERS' IRRIGATION COMPANY OF MERCED.

The Farmer's Irrigation Company of Merced was formed to bring down water from the Merced river at a point near Snelling, for irrigation upon the plains between that river and Bear creek, and from the foothills to the San Joaquin river. Among the leading parties connected with the enterprise are William G. Collier, the Messrs. Cressy brothers, Upton, Fowler, Douglas, Morrison, Gray, Elliot, Jolley, Fitzgerald and Rogers—all farmers within the district to be improved. The company has succeeded to the water rights of the Robla Canal Company, an organization formed in 1870 to carry water for irrigating purposes into the Bear creek country, which took up the water claim on the Merced river, referred to above. Under the rights of the Robla Company, twelve miles of uncompleted canal have already been constructed, at a cost of $20,000, between the Merced river and Bear creek—dimensions, bottom 50 feet; top, 80 feet; hight, 3 feet—to be increased to 5 feet. As rapid a descent as can be safely allowed in grade is one foot to the mile, giving a velocity to the water of about two feet per second. At this rate the discharge of a canal of the above dimensions will be 400 cubic feet per second, sufficient to give during the season a depth of twelve inches of water over 80,000 acres. Upon much of this Merced and Bear creek land it is thought that one good wetting with four inches of water, after the crops are well started, will suffice to mature them, and would render the supply of the Merced Farmers' Canal adequate to the actual necessities of over 300,000 acres.

The proposed canal will start from the Robla Company's water claim above Snelling and follow down the foothills a distance of five and a half miles to a point on the divide between the Merced and the Bear. Here the canal branches, one part carrying one-fourth of the water, going into the channel of Canal creek, which it pursues some distance, and is then taken out and carried across to the Bear above the point known as the Roblas, whence the original enterprise takes its name. From the fork of the canal the second and main branch, carrying three-fourths of the water, makes a long sweep around the tongue of the divide, keeping well upon the flank, until it crosses the Bear at a point nine and a half miles east from the town of Merced and passes in a broad sweep southwestwardly into the San Joaquin. The lengths of the several portions of the proposed works are: From the head to the fork of the canals, five and a half miles; thence by the line of the main fork to Bear creek, thirty-three miles; thence to its debouchment in the San Joaquin, twenty-two miles—total length, sixty miles. Final surveys have not yet been made for those specifications of construction that determine the cost. The headworks, it is stated, will be inexpensive, which perhaps means that they will cost less than $10,000. South of Snelling, in order to come out upon the divide, the water will have to pass through a 1,500-foot tunnel. If this tunnel be given an inclination of twenty feet per mile, or five feet eight inches in the 1,500 feet, and be six feet wide by five feet deep, it would discharge the quantity of water carried by the main canal, which would have a velocity in the tunnel of thirteen feet per second. It is thought that this tunnel, or a part of it at least, can be safely left without timbering. The material is a lava, which works freely under the pick. But moving at the velocity assumed, the water would possess such power of erosion, perhaps slowly caving the mate-

rial, which would then be deposited in the canal and thus endangering the permanence of the whole work, that prudence may demand the lining of the tunnel throughout with timber. The cost of the mere excavation may be set down at $10,000, to which add whatever outlay is made for timbering. The cost of making the canal in the open country is estimated at $2,000 per mile—a figure likely to be exceeded on parts of the line. The total cost of the work on the basis of these figures would then be as follows: Headworks, $10,000; tunnel, $10,000; five and a half miles of the fork of the canal, $11,000; thirty-three miles of main fork to Bear creek, $66,000; twenty-two miles from Bear creek to the San Joaquin, $44,000. Total, $141,000. To this is to be added the cost of 600 feet of fluming crossing intervening creeks, including the Bear; also of carrying the smaller fork from Canal creek to the lands it is designed to serve, but this will not be considerable. The interests of the principal parties connected with the enterprise are served when the canal reaches Bear creek, and there it may stop awhile awaiting action of the farmers living between that point and the San Joaquin river. To Bear creek the cost, according to the above figures, should approximate $97,000. It is stated that the necessary funds are already subscribed by the responsible parties, many of whose names are mentioned above, and the work is now in process of construction.

LOWER KING'S RIVER DITCH.

The People's Ditch Company of Tulare is an organization formed by the settlers on the lower King's river section, who are constructing an irrigating canal for the benefit of their farms. Water is taken from the river at a point ten miles above Kingston by a simple headgate without a dam. The course of this ditch, as laid out and now well advanced in construction, is to a point known as "Lone Tree," distant fourteen miles from the head. Thence to the lake the distance is seven miles, through which the work may be extended should settlers in that locality see fit to take it up. This ditch is laid out to carry four feet depth of water with a width at the top of twenty-five feet. Toward the head the banks are constructed with a slope of only one-half horizontal to one vertical. At the same time the grade is considerable, falling at the rate of several feet to the mile, while at one point the steep rate of two feet in seventy rods was adopted. The material of the bank at this point is not of special tenacity. It remains to be proved by experience, therefore, whether the stability of the banks under these circumstances can be maintained, the detail of the construction being in violation of the rules laid down in the engineering manuals. The money for this work was raised by the formation of an incorporated company, with a capital stock of 100 shares of $100 each. Each subscriber is an owner of 160 acres of land, and their calculation is that each, taking an equal share of the water run by the ditch, will obtain sufficient for the irrigation of his quarter-section. Whether or not they will find that they have all the water they would like, certain it is that each will get enough to repay him an hundred fold the amount of his investment in the enterprise. Although this work is not projected on a plan to form any part of a general irrigation system, it does not interfere with such an one, and illustrates what may be done by the co-operation of a few neighbors in procuring present benefit for which they might, by depending on the construction of the greater works, have to wait for years.

UPPER KING'S RIVER DITCHES.

At Centerville, on King's river, twenty miles above Kingston, two small ditches have been partly constructed by the joint efforts of owners of land at that point and owners in lands of the San Joaquin Valley Land Association, lying between Centerville and the town of Fresno, on the railroad. The principal of these ditches utilizes for a considerable portion of its length the channel of a small, natural slough. The ditch is some fourteen miles long, about eight feet wide, and runs over a foot of water in depth. The amount of water supplied is, however, insufficient for the needs of the owners, outside of whom are a considerable number of settlers whose needs are equally imperative, while the settlement at Fresno, which is a growing one and will soon become an important town like Merced or Modesto, requires a copious water supply. A second small ditch running nearly parallel with that above described has been constructed for several miles. The settlers who are now without water propose combining with the citizens of Fresno town and the owners of the second ditch to increase its dimensions, to alter its course so as to serve a greater area of country and to carry it into the town. These ditches get their water from King's river by aid of a small dam. Neither of these enterprises,

however, even as projected, is adequate to the needs of the irrigable land of superior quality lying in this section, a very large body of which is on the west side of the railroad, of which the needs have not been considered or provided for at all. Nor could these become main parts of a general irrigation system. The labor expended on their construction need not, however, be wholly lost; whenever a general system shall be constructed, it is probable that these works could be utilized as distributing ditches

CHAPMAN'S CANAL.

Between the Alabama settlement, which is supplied with water by Mr. Friedlander's Fresno river canal, heretofore described, and the San Joaquin river, bordering on the latter, lies a considerable area of fine irrigable land, owned principally by Lux, Miller and Chapman. This is west, and some fifteen miles distant from the Fresno canal. To irrigate these sands a work known as Chapman's Canal, partly constructed last year, is in progress. It takes the water from the San Joaquin river, on the east bank, at a point twenty-five miles above Firebaugh's ferry and fifteen miles from the magnificent railroad bridge over that river. No dam is used. The head works consist of a flume thirty-five by thirty feet, founded on two rows of sheet piling. The head-gates work ten feet above the flume. The flume opens into a head basin of oval form, 40 feet in the lesser by 120 feet in the greater diameter. From this the canal, having a width of twenty feet, to run some three feet depth of water, proceeds northwardly, its course surveyed to strike the Chowchilla river at the Montgomery (Chapman's) ranch. Head works such as those of this enterprise can be constructed at a cost of $5,000. The canal itself may cost perhaps $2,500 per mile in average ground.

THE KING'S RIVER AND SAN JOAQUIN COMPANY'S CANAL.

The most extensive and important of these enterprises yet put under construction, a canal for navigation as well as to supply water for irrigation, remains to be described. The San Joaquin river comes down from the Sierra Nevadas in a westerly course, and at a point a few miles above (south of) Firebaugh's ferry makes a bend to the northward. The drainage of the great territory which empties into Tulare lake as a reservoir, comes down thence northwardly during the period of overflow through a line of main sloughs, and empties into the San Joaquin at this bend. The channel of this overflow at the point where it empties into the river, known as Fresno slough, always contains water, and during the season of high water is navigable to its head. Between the head of Fresno slough and Tulare lake are two other sections of deep channel known as Buena Vista and Fish slough. This, however, does not extend to the lake. If, now, the three isthmuses between Fresno, Buena Vista and Fish sloughs and the lake be cut through, a navigable channel becomes established from Kern county, at the southern end of Tulare lake, to the junction of Fresno slough with the San Joaquin river above Firebaugh's ferry. Were the navigation of the San Joaquin permanent to this point, navigation would thus be opened from near Bakersfield, and embracing the magnificent lands known as the Tom creek country, to the bay of San Francisco. But at its lower stages the upper San Joaquin is not navigable, the present head of permanent navigation being at Moore's Landing, near the crossing of the Western Pacific Railroad. To complete the chain of navigation outward from Tulare lake, it becomes necessary therefore to construct a navigable canal from the mouth of Fresno slough to Moore's Landing. This is the canal which the San Joaquin and King's River Canal Company have now under construction, and of which a large section is already completed. There still remains a section of some seventy miles to construct between the present lower end of the canal near Kreyenhagen's, at Los Banos creek, and Moore's Landing.

In the San Joaquin river, near the mouth of Fresno slough, is an island which divides the stream into two unequal portions—the western one being the smaller. From this smaller channel the canal takes its water by means of a dam of admirable construction. Across the main channel on the east side of the island a brush dam is thrown in order to maintain a full volume of water in the lesser channel. The canal dam consists of two rows of sheet piling, the space between them filled in and planked over. The piles are four inches thick. Upon this main dam as a foundation is erected a frame carrying gates which move up and down, the water flowing over their upper edges. Thus, when the channel is running full, by lowering the gates the entire volume of water is allowed to flow freely over the dam. As the quantity of water diminishes, the gates are gradually

raised, maintaining the surface of the water behind them at an uniform level. The construction of this dam, like that of the Fresno canal, was carried on last winter at a time when the streams were running full, and involved some nice exhibitions of engineering skill. As an example of the class of devices resorted to in battling with the swollen torrent which opposed every portion of the work, one operation may be described. After the upper row of sheet piling had been driven the water boiled through between the piles, as well as over them, with such violence as to carry off the filling between the two rows of piling as fast as it could be dumped in. To overcome this a sufficient number of stout sails were procured to extend the entire length of the dam. Heavy sand bags were attached to one end of the sails. A gang of men, as many as could stand side by side on the dam, strung the sails with the bags attached from one end to the other. A powerful current poured over the top of the piles, and against this the men slowly shoved the line of bags until it rested on the edge of the upper row of piling. At a word the bags were pushed over and immediately sunk to the bottom, the upper edge of the sails remaining attached to the top of the piles. The sails formed an effectual barrier to prevent the current pouring between the piles, and though the entire volume of water now flowed over the top, the operation of filling in between the two rows of piles was successfully prosecuted, and soon the main dam was completed.

This dam turns the water into the main canal through a sluice. The gates of this sluice also work so as to allow the water to flow over them. The advantage of this arrangement over that of allowing the water to flow under the gates is that in the latter case the stream, under the pressure of the "head" behind the gate, is discharged into the canal at a high velocity tending to cut away the banks; in the former case the stream tumbles into the sluice by a waterfall, the energy of which is expended in boiling around in the sluice, whence it flows into the canal in a tranquil stream.

The dimensions of the canal are: Width at bottom, thirty two feet; slope of banks, three horizontal to one vertical; depth of water, six feet; width of water at surface, therefore, sixty-eight feet. The banks are carried two feet above the surface of the water, and are made wide enough on top for a tow-path and foot-way respectively. Running in a line substantially parallel with the axis of the valley, the fierce winds which sweep over these plains from north to south throughout the summer season raise a strong ripple on the waters of the canal, actually curling the waves over into small "white-caps" and illustrating with some force the old song anent "the raging canawl." This ripple is, however, a source of substantial inconvenience in washing away the adobe banks of the work. To counteract it, these banks are being lined with brush pinned to the bank with the butts upward, which has been found to give the needed protection. Up to the present date the canal has been run with only four feet depth of water; the work done this year, now approaching completion, has been to raise the banks so as to admit the full depth of six feet of water. The present lower terminus of the canal is at Kreyenhagen's, in Merced county, forty miles below its head at Fresno slough, and seventy miles above Moore's Landing—the head of permanent navigation on the San Joaquin. Kreyenhagen's is 100 miles from Antioch, in Contra Costa county. The canal company has proposed to the farmers and land owners between Kreyenhagen's and Moore's Landing to subscribe a portion of the stock necessary to extend the work to that point; or if sufficient stock should be subscribed for, the work would be carried to Antioch—the more advantageous plan. Neither proposition has been responded to. The purpose of the company is to suspend further extension northwardly for the present. To the south, connection will be made between Fresno slough and Tulare lake by way of Fish and Buena Vista sloughs, heretofore described, by cutting through the isthmuses which now separate those channels. Navigation will thus be established between the lake with the vast area of country accessible to it and Kreyenhagen's. When the central canal shall be extended to Moore's Landing that country will be in communication by permanent water navigation with the Bay and ocean.

These works have been constructed by Mr. M. Hangroom, civil engineer. Among the gentlemen prominently connected with the enterprise as projectors and builders are Messrs. John Center, J. Mora Moss, Henry Miller, George H. Howard, I. Friedlander, Charles Lux and others, to whom must be added Mr. J. M. Brereton, civil engineer, for some years past prominently engaged on the

Government irrigation works in India. This gentleman, who is consulting engineer, projected the present works, and by his exposition of their advantages gave the impulse that led to their construction.

THE SYSTEM IN PRACTICE.

CANAL NAVIGATION OPENED.

The Californian who inspects these works for the first time will be fortunate if his first intimation of their proximity shall be the sight of a mast sweeping along the plain, a tow-line from the head of which, together with the familiar motive power at the end of it, shall quicken to his imagination with all force and consequences the grand fact that canal navigation has opened in California. The first four boats were constructed by the company for the transportation of their own material and supplies. They are built upon an English model, less cumbersome and "logy" than the American canal boat—dimensions, sixty-three feet length by nine feet eight inches beam. This boat carries sixteen tons weight to each foot of draft. A movable gunwale permits them to be loaded to a draft of four feet—i. e, to carry a cargo of sixty-four tons. Thus loaded, they are towed with the stream (northwardly) by a single animal as rapidly as he can walk. Returning light, the same beast furnishes sufficient power to move the boat up stream. Larger boats of similar model have since been constructed. These facts, thus boldly stated, need no elaboration to enable the intelligent mind to grasp their bearings upon the "transportation problem" which still engages so much of the public attention. They show how the canal tends to neutralize distance from tide water as an element in the determination of land values; how it brings the rich river bottoms of Tulare and Kern counties as near to market as many lands in the Bay district itself; how it renders possible the profitable cultivation of small grains in regions where the advent even of the railroad still leaves the farmer hopelessly beyond reach of the export market. To the dwellers on the upper Sacramento it is not less important than to those on the San Joaquin, and points a significant finger to the direction which may profitably engage energies and resources that have heretofore spent unprofitable force on schemes of narrow gauge railway. California has made one great bound in the path of wealth since the opening of her Railway Era. Here we see, in the silently moving and heavy laden canal boat. the dawn of a second Era whose fruits shall be not less important than the first. Will they not, in fact, far transcend them in magnitude? Is it not plain that these two elements of transportation working together present the solution, in its full sense, of the problem which is before the country? The great bulk of produce from the soil, low in value to the ton but aggregating millions of money in its many thousand tons, floats with slow, uncostly motion to the sea; while the produce of industry, charged with the value of the labor of many hands, and the busy population whose time is money, glide swiftly along the ringing rail. Words very imperfectly shadow out the full fruition of this new element in our progress—Canal Navigation—compared with the illumination which seems to flash upon the mind with the first ocular view of the accomplished fact.

Irrigation in Practice.

In describing the Irrigation works, their two principal features—the Main and Distributing canals—have been explained. The next step is to consider the means and method for the actual application of the water to the ground. The first work of the farmer is to construct his own farm ditch. This lies wholly on top of the ground. The material for the banks is taken from outside their line, so that the water flows wholly upon the surface of the ground. The distributing canal from which the water is to be taken will always be higher than the highest point of the farmer's land. He will therefore be able to lay out his own ditch so that the water in it shall flow on the surface of the highest land he has to apply it to. The water will be discharged from the distributing canal into the farm ditch by a gate which will at once measure and regulate the amount of water delivered through it. To take the simplest case we will suppose the surface to be irrigated to constitute a perfect inclined plane—as it would in fact on the west side of the San Joaquin—160 acres in extent, lying in the form of a square, each side a half mile in length. Then a ditch half a mile long following the western boundary of the field would serve to irrigate it. In the east bank of this ditch three gates would be placed, one at each end and one in the middle, distant from each other one-fourth of a mile. From

each of these gates a furrow is run east at right angles to the ditch to the opposite side of the field. As the ground slopes east at the rate of eight feet to the mile, it will slope four feet in the half mile, which is the width of this quarter section. And it will slope four inches in each 224 feet—say thirteen and a half rods. Twelve times this distance reaches the lower side of the field. Throw up, then, with a plow twelve ridges running north and south the entire length of the field 224 feet apart and each at least four inches high. These may be called "checks." To irrigate this ground, open the gates from the farm ditch and turn in the water. It will flow down the three east furrows. Throw with the hoe a little dam across each furrow 224 feet east from the ditch—i. e., at the points of intersection with the first "check." When the water reaches these dams it will back up till it begins to overflow into the field, where it will be held in the "check" till it stands four inches deep at that line, while its surface will exactly intersect that of the field at the foot of the ditch bank, distant 224 feet west. The first belt of the field next the ditch having been thus thoroughly irrigated, clear out the furrow dams and hoe up three others 224 feet east from the first, or at the points of intersection of the furrows with the second "check," repeating the operation till the field is irrigated throughout its length and breadth. In this, its simplest form, the labor of irrigation is inexpensive. How often the water need be applied in an ordinary season to make one crop will be proved by experience. It is said by farmers on the adobe lands of the west side of the San Joaquin that four inches of rain coming in the latter part of the season is sufficient to make a crop. There is no obvious reason why an equal quantity of water applied by irrigation should not accomplish an equal result. In some of the successful experiences that were had last year a larger quantity was consumed; but the fact is well attested that in these operations far more water was wasted than was utilized, through inexpertness in applying it.

The intelligent reader perceives that the method of applying the water to the land by this system of furrows following the line of steepest inclination, with "checks" connecting those furrows at right angles to their direction, is as applicable in all its detail to the "uneven" lands east of the San Joaquin as to the absolute inclined plane of the west side. The only difference in method is that diversity of directions to be taken by the furrows which was indicated in the preceding description of the "uneven" lands. The distances to be left between the "checks" and dams to give equal depths of water at each irrigation depends on the inclination of the surface diminishing as the degree of slope increases. If a greater depth of water be given at one time, the distance between the "checks" may be increased, but the distribution cannot be made equally uniform. Those portions of the field next above the "checks" and on which the water stands deepest will absorb a greater amount than the more distant portions, on which it is shallower. By increasing this depth much above four inches it would not be difficult to drown out a portion of the crop while another portion should fail to receive sufficient for its needs. Some irregularity of distribution is inevitable, but the nearer together the "checks" are put, and the less the depth of water given at one time, the more uniform will be the effect. It is plain that the results of farming with irrigation, as of that without irrigation, will differ under the hands of different men; and that, in the one case as in the other, the more intelligent operator, and who is willing to give more downright honest work to his operations, will achieve the best results.

On the inclined plane lands of the west side the detail of applying the water may be varied. The farm ditch may be run on an east course, on which the land falls at the rate of eight feet to the mile. It will also fall away from the north side of this ditch at the rate of one foot to the mile. Main irrigating furrows run from this ditch both northeast and southeast will have a rate of inclination intermediate between these two—slightly greater for the northerly set, but the difference would be inappreciable in practice. These furrows could be run so that each northeast furrow from one ditch would meet the corresponding southeast furrow from the ditch next north of it. Thus an irrigating system would be laid out upon the whole surface of the ground resembling the skeletons of fishes, whereof the several farm ditches would be the backbones, each with its system of ribs attached formed by the main irrigating furrows. This is in fact the plan that was adopted last season by the canal company in laying the water on the 5,000 acre field which they have rented as a sort of model farm from Lux & Miller. The water is applied through this system by the same method al-

ready indicated — alternately throwing up and hoeing out a succession of dams across the irrigating furrows, backing up the water in them till it overflows the adjacent soil. The proper series of "checks" produces the necessary uniformity of distribution to each part.

All streams flowing from the Sierras which are not charged with the mud from mining operations, bring with them extremely minute particles of inorganic matter. Stooping upon the edge of the stream, the sun's rays being in the right direction, some of these particles —probably micaceous scales—can be perceived. If a sufficient quantity of the water be collected and allowed to settle, this matter will be deposited as an impalpable slime. In this state it is the perfection of manure—the sustenance of plants in the form under which they can most readily assimilate it—the true fertilizing slime of the Nile. In seasons succeeding a general overflow of the Tulare streams the vegetable growths are of an exceptional luxuriance; the yield of cultivated crops reaches nearly incredible figures. Much of the soil that is thrown up to make the canal banks is light and sandy—at points, as in crossing old river beds —an apparently pure sand which, it might be supposed, would be incapable of retaining water. Yet the water does not percolate through the banks, and when these are examined after the flow has continued awhile it is found that the inner layer has become cemented together and is as impervious to water as rock. The slimy material has filled the interstices between the particles of sand and compacted them into a solid mass.

REVIEW OF THE FIELD.

FUTURE OF THESE PLAINS—SOME DETAILS.

With the lights now before us, it is not difficult to foresee approximately the course of settlement by which these great plains will be developed. This will follow the desirable soils, keeping closely to those which can be relied upon to make a crop, and among such, preferring the lines of transportation, whether by canal or rail. These soils are: 1. The heavy adobes of the west side of the San Joaquin river in general. 2. The adobe belt that crosses Stanislaus eastwardly, of which Modesto is near the center. 3. The adobe belt that crosses Merced eastwardly, of which Merced is near the center. 4. The broad tract of loam adjoining the railroad at Borden station, in Fresno county (the Alabama settlement), now irrigated by the Fresno canal (Friedlander's), and the body lying east, irrigated by Chapman's canal—under construction. 5. The still larger belt of loam that crosses the railroad at Fresno city, coming westwardly from the upper King's river bottom at Centerville, embracing the German settlement (San Joaquin Valley Land Association), together with an extensive tract west of the road, all of which to be made available requires a canal of the first class from King's river. 6. The extensive and wonderfully rich (but feverish) loam bottoms of Tulare county, embracing lower King's river, the Four-creek and Tule river country, together with the vast adobe plains adjacent to Tulare lake. 7. The still more extensive adobe plains and moist bottom loams of Kern county. By examining what is needed by each of these localities and what is doing and in prospect of being done to supply such needs, the course of development and local progress will unfold itself.

THE WEST SIDE.

The west side of the San Joaquin, in general, needs (1) irrigation and (2) transportation. This area may be considered in three parcels—first, that north of the present terminus of the canal—i. e. between Kreyenhagen's and Moore's landing; second, south of Kreyenhagen's and west of the canal, between it and the hills; third, south of Kreyenhagen's and east of the canal, between it and the river. The whole of this section is supplied with transportation by the river during the period of high water, so that it can "get along;" the season is brief but long enough to get moderate sized crops out of the country. Still, for three-fourths of the year, canal navigation would be a Boon. Irrigation, the first thing needed, will come to that section of the plains first above named, whenever the canal shall be extended northwardly. The second named section will not get irrigation till another main canal shall be constructed from Tulare lake down along the west foothills—a work of which there is no immediate prospect. The third section is that irrigable from the canal as now built. This area may be said to be ready for occupation.

THE EAST SIDE.

For the lands of the east side the railroad is the channel of transportation. If the far-

mers of that extensive adobe belt whereof Modesto is the center, conclude to construct irrigating works they have an abundant supply of water in the Tuolumne and Stanislaus rivers. The next great belt of adobe at Merced can be irrigated from the Merced river, and works for this purpose have, as heretofore explained, been projected by local enterprise. But these two tracts can, perhaps, make a living without irrigation; they will hardly, however, grow rapidly rich. The extensive body of loam at Borden station (the Alabama settlement) is irrigated by Friedlander's canal. East of this, near the river, and extending away northwardly to the Chowchilla, lies the extensive body owned chiefly by Chapman, Lux and Miller, to be irrigated by the Chapman canal. These two sections may also be described as ready for occupation. Next south, the still larger tract of choice land (valuable without irrigation), extending from Centerville to the railroad, and for a distance some miles west of it, seems to have no immediate prospect of adequate irrigating works. The two ditches previously described may be sufficient to enable the parties directly interested to cultivate their own lands, or a considerable part of them, but they are not even projected on a scale to serve the entire area; and until works of this character are in prospect, settlers will give preference to more favored localities.

THE TULARE COUNTRY.

The Tulare loam bottoms need only transportation for the development of great wealth; the adobe soils in some localities may need irrigation as an assurance against failure of crops. But there is a great deal of adobe in this county that can be relied upon to mature small grains with quite as much confidence as some other parts of the State that are regarded as in the first rank of agricultural lands. East of lake Tulare there is more rain than on the plains north, and vast tracts of adobe lie so low and flat, being overflowed, or on the margin of the overflow, that they retain moisture sufficiently late in the season to mature crops of small grain. A good deal of the loam repays irrigation, but such as is needed can be had, and is being secured by local effort. Irrigation works of an extensive sort are not prerequisite to the development of large wealth in Tulare. But cheaper transportation is essential to rapid development. Tulare lies beyond the reach of a profitable export market by rail. The prospect therefore of the establishment of canal navigation between the lake and the lower San Joaquin is, to Tulare, an opening of the door to wealth and development unlooked for, if not undreamed of. There will remain to this section only the drawback of the fevers that prevail over much of the richest lands. These may deter settlement. The irrigation works proposed in this county take mainly the form of leveeing the lakes and the rivers, preventing the periodical overflow, and thus tending to obviate the cause of malaria. It is from this point of view that the proposed works are, perhaps, most important to that section of country. When these works shall be accomplished, if not before, it is not difficult to see that Tulare will become, in some respects, what portions of Louisiana were before the war, the seat of an exceptional wealth, and prominent even in this favored State, for the variety and luxuriance of its productions.

To Kern county, the general remarks made of Tulare, are applicable. "The Island" (so-called) whereof Bakersfield is the business center, can scarcely be rivaled in the State for richness of soil, and for a climate calculated to urge every product to the most prodigal development. But the stranger shrinks from the malarious influence which the execution of judicious irrigation works would be calculated to mitigate and in time eradicate altogether.

SUMMARY.

The foregoing review has developed the conclusion that, with the exception of two localities, the works essential to the immediate development of the great southern interior plains are under actual construction, and will be completed for the present planting season. These exceptions are—first, that part of the west side of the San Joaquin lying north of Kreyenhagen's, and second, the loam belt on the east side that crosses the railroad at Fresno city. Modesto and Merced can live along without irrigation, and can readily get it if they conclude that they want it. The loams of the east side at the Alabama settlement and Chapman's, are supplied. So is the adobe next the river from Firebaugh's north to Kreyenhagens. The Tulare county does not need irrigation in the main, but does need canal transportation, and is in the way to get it. It more needs to have its waters leveed within their banks, and it is "on the cards" that that will come

among the first new developments of the canal and irrigation system. The area of land to which water for irrigation is actually supplied this year is some 150 square miles. Of this, the area supplied by the San Joaquin and King's river canal as now constructed—i. e., the area lying between it and the San Joaquin river, extending from the headworks to Kreyenhagen's, on Los Banos creek, is 48,490 acres. The extension of the canal, north, will cause it to intersect the Western Pacific Railroad at a point near Ellis station The irrigable area between this point and Los Banos creek, the present terminus, is 100,678 acres. Of equal significance are the areas served by the canal as a channel for transportation. To ascertain these, add to the area commanded by it for irrigation, that of a strip three miles in width on the western or upper side of the canal. We then have to add for the section already completed 69,632 acres, making a total, with those also irrigable, 118,122 acres. If the canal be extended to Ellis station, a further area will be served for navigation equal to 113,788 acres, making a total, with those also irrigable from the same extension, 214,466 acres. With the completion of the canal southwardly to Tulare lake, it will serve for navigation, adjacent to its banks, the further area of 74,133 acres. But, it is to be remembered, by establishing a connection with lake navigation the whole vast area of Tulare and Kern counties adjacent to the lake, are equally brought within the benefits of canal navigation. The total area contiguous with the canal which it would serve for navigation between its point of union with Tulare lake and Ellis station, would be 406,721 acres—a figure, it may be added, so great that it conveys to the mind no definite idea of area. Its capacity, when all cultivated under irrigation, may be stated as equal to that of any equal number of square miles of the richest virgin soil ever turned in California in its most favorable season. The area hitherto beyond reach of market, to which a market is to be brought by canal navigation, is some 250,000 or 300,000 acres of the very richest and most productive soil in California. Concerning the larger features of a comprehensive canal system for the entire State, with a main lateral canal along the foothills on each side of the plains, it is obvious that the one projected for the east side can wait; most of the good that it could accomplish is in process of being accomplished by the minor works already in progress or in prospect. The main canal on the west side could be executed with advantage, creating a high value upon nearly every acre of the vast plains upon that side of the San Joaquin river. The leveeing works proposed in Tulare county would tend to remove the last drawback upon what is already both the richest and loveliest spot on all the surface of California.